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TEMPORAL TRENDS IN FREQUENCIES OF MELANIC MORPHS IN CRYPTIC MOTHS OF RURAL PENNSYLVANIA

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ABSTRACT. Five species of moths with recorded melanic forms were light-trapped for 10–16 years during 1971–86 at a remote mountain valley in E-central Pennsylvania. Observed melanic frequencies were: *Biston betularia cognataria* 0.52 (1971–78) and 0.38 (1979–86); *Epimecis hortoria* 0.34; *Phigalia titea* 0.14; *Charadra deridens* 0.64; *Catocala ultronia* 0.001. All but *Biston* showed constant melanic frequencies during their sampling periods.

Additional key words: Geometridae, Noctuidae, *Biston betularia cognataria, Lymantria dispar.*

Many eastern North American nocturnal moths that escape daytime predation by cryptic resting behavior have a moderate frequency of heritable dark forms. A simple working hypothesis to explain the adaptive advantage of this phenomenon is that these are "industrial melanics", favored by industrial and automotive pollutants in the atmosphere (Kettlewell 1973). Such an hypothesis is only vaguely supported in North America because of inadequate records. If trends showing systematic increases or decreases in frequency of melanics can be documented, the causes of such shifts might be found.

A second major body of relevant evidence results when enough localities are sampled for melanic frequencies. With these possibilities in view, I have been obtaining melanism data from daily light trap samples in a rural wooded valley for 16 years. The first eight years (1971–78) of records for *Biston betularia cognataria* (Guenée) (Geometridae) were presented and discussed previously (Manley 1981). In the present paper, data are given for *B. b. cognataria* for the next eight years (1979–86) as well as the first eight, and comparative records are included for *Epimecis hortoria* (F.), *Phigalia titea* (Cramer) (both Geometridae), *Charadra deridens* (Guenée), and *Catocala ultronia* (Hübner) (both Noctuidae). The observed melanic frequencies are compared with each other and with published records from other areas.

Materials and Methods

Sampling (dusk to dawn) was conducted nightly from April through early September each year using a fluorescent 15-watt blacklight and a mercury-vapor light trap. The trap was located in an isolated mountain valley 12 km NE of Klingerstown, Schuylkill Co., Pennsylvania. Except

TABLE 1. Melanic frequencies in four species of moths near Klingerstown, Pennsylvania. The two annual broods of *Biston betularia cognitaria* are combined. Dash signifies no observation.

	Biston b. cognitaria		*Charadra deridens*		*Epimecis hortoria*		*Phigalia titea*	
Year	Frequency	N	Frequency	N	Frequency	N	Frequency	N
1971	0.52	588	—	—	—	—	—	—
72	0.51	669	—	—	—	—	—	—
73	0.56	828	0.68	35	—	—	—	—
74	0.52	272	0.58	52	0.47	15	—	—
75	0.52	102	0.62	50	0.35	15	—	—
76	0.53	219	0.80	5	0.38	21	—	—
77	0.51	244	0.67	15	0.33	55	0.14	176
78	0.46	226	0.71	7	0.23	13	0.17	189
79	0.48	452	0.73	11	0.29	68	0.15	148
80	0.52	68	0.86	7	0.25	24	0.17	219
81	0.43	30	0	0	0.14	7	0.20	257
82	0.36	100	0	0	0.22	40	0.15	31
83	0.34	466	0	0	0.42	52	0.15	180
84	0.33	196	0.67	12	0.31	74	0.18	211
85	0.34	239	0.75	4	0.37	87	0.15	93
86	0.38	301	0.75	4	0.38	60	0.10	33
Total	0.47	5000	0.65	202	0.33	531	0.15	1537

for a few open fields, the area is tree-covered. Details of site, sampling methods, and regional sources of air pollution potentially affecting air quality and melanic frequency are given in Manley (1981). Sampling extended over a period of 10 or more years for each species. Specimens were pinned with full data and are part of the Manley Collection, Peabody Museum of Natural History, Yale University.

The data format in Table 1 allows quick comparisons with Owen (1961, 1962), Sargent (1971, 1974), and Klots (1964, 1968). *G*-tests using Williams's correction (Sokal & Rohlf 1981) were employed to test whether melanic frequencies differed from year to year.

RESULTS

Biston betularia cognataria appears to undergo large fluctuations in population density every 4–5 years (Table 1). In 1975, the first brood consisted of 3 trapped specimens followed by a second brood of 99, with the melanic frequency of 0.52 equal to the first 8-year average (Manley 1981). The melanic frequency declined from 0.52 in 1980 to 0.33 in 1984, while numbers trapped rebounded to levels before the population crash of 1980–81. Populations after 1981 show a six-year (1981–86) melanic frequency of 0.34, compared to 0.48 for the 6-year period (1975–80) following the 1975 crash. This contrasts with a frequency of 0.53 for the first 4 years (1971–74).

The 1971–78 trends in *Biston b. cognitaria* were earlier interpreted partly as a gradual decline in melanic frequency (Manley 1981). The new data here strengthen this suggestion (linear regression of melanic frequency against year: slope = -0.016 ± 0.002, N = 16, $t = 7.27$, $P < 0.001$). However, an equally plausible explanation is the population crash of 1981 (1971–80 data versus 1981–86 data: $G = 132.47$, df = 1, $P < 0.001$; samples in 1971–80 set are homogeneous, as are samples in 1981–86 set, $P > 0.25$ by G-tests).

Epimecis hortoria (Table 1) exhibits a stable frequency of 0.33 for its melanic form "*carbonaria*" ($G = 9.98$, df = 12, $P > 0.50$). This moth has become increasingly abundant at the light trap since its population crash in 1981. Owen (1961, 1962) reported a 1957 sample of 8 specimens from Westmoreland Co., just E of Pittsburgh, as 100% melanic, and a 1959 sample at Lebanon, Hunterdon Co., New Jersey, as 0.90.

The melanic form "*deplorens*" of *Phigalia titea* is distinct, with no apparent intermediates; it (Table 1) maintained a stable frequency of 0.15 during the sampling period ($G = 3.66$, df = 9, $P > 0.50$). Owen (1961) reported 1960 melanic frequencies in Michigan ranging from 0.11 to 0.14; Sargent (1971) reported 1968–70 melanic frequencies at Leverett, Massachusetts, at 0.20.

My samples of *Phigalia titea* were taken 25 March through 5 May. Since this moth begins flying on warm March nights, a portion of the total possible sample of it was probably not taken. My samples reflect only warm nights in late March with no continuous sampling until April. Nevertheless, there does not appear to be substantive change in melanic frequency of this species.

Melanic frequency for *Charadra deridens* during 1973–86 (Table 1) was stable at 0.65 ($G = 3.89$, df = 9, $P > 0.50$). Klots (1968) at Putman, Windham Co., Connecticut, reported limited 1961–66 samples (N = 28) to be 0.89 melanic, and a laboratory reared sample (N = 39) to be 2:1 melanic.

Charadra deridens samples have been small since 1981–83, when no moths were taken (Table 1). The 10-year melanic frequency of 0.65 is the highest of any melanic moth sampled to date at this locality.

Catocala ultronia, the most abundant *Catocala* in central Pennsylvania, was sampled during 1968–78. In my sampling, only 2 of 1520 specimens were the melanic form "*nigrescens*", all others being color variants of form "*celia*". Sargent (1974) reported the 1968–74 melanic frequency in Leverett, Massachusetts, to be 0.17 (N = 586).

DISCUSSION

Except for *Catocala ultronia*, the species discussed in this paper show strong melanic tendencies. Melanic frequencies differ from those observed at Leverett, Massachusetts (Sargent 1974), even for the same years. Melanic frequency appears to fluctuate independently at least in part among species. Some factors affecting melanic frequencies are presented in Manley (1981).

The 1980–81 season heralded severe reductions in the populations of *Biston, Epimecis* and *Charadra,* whereas *Phigalia* produced the largest sample of its 10-year period, only to be reduced to 31 individuals in 1982. An explanation for the sudden reductions in population densities could in part be local infestation of the deciduous woods by the gypsy moth, *Lymantria dispar* (L.). A partial defoliation in 1980 was followed by severe defoliation in 1981 and aerial spraying with Dylox or Dimilin by the Pennsylvania Department of Forestry. Spraying was discontinued in 1982, and no noticeable defoliation has occurred since.

Four species in this study are polyphagous. More than 50 species of trees and shrubs are recorded for *Biston betularia cognitaria,* with *Salix, Populus, Betula,* and *Alnus* preferred (Rindge 1975, McGuffin 1977). Prentice (1963) lists 25 species of hard and softwoods for *Phigalia titea,* with *Tilia, Ulmus, Betula, Populus, Acer,* and *Quercus* preferred. *Epimecis hortoria* prefers *Liriodendron, Sassafras,* and *Prunus,* and is rarely found on other deciduous trees (Forbes 1948). *Charadra deridens* prefers *Ulmus, Betula,* and *Quercus* (Forbes 1954). Only *Quercus* among the preferred food plants is normally eaten by the gypsy moth. Aerial spraying to control gypsy moth may have been a critical factor in reducing populations of the polyphagous species. The rapid recovery of *Biston* and *Phigalia* following reductions in 1981–82 (Table 1) could be attributed to the wide range of food plants acceptable to these species. Similarly, the preferred food plants of *Epimecis* are not those eaten by larvae of the other species in this study, thus perhaps accounting for a rapid recovery in 1982. *Charadra deridens,* a *Quercus* feeder (Forbes 1954), appears to have been severely reduced in the defoliated area, as none were trapped from 1981 to 1983, and it remains rare in the area (Table 1).

The population reduction of *Phigalia* in 1982 does not coincide with the 1981 reductions of the other species (Table 1) in that the annual sample was taken before the aerial spraying in 1981.

Defoliation by gypsy moth opens the forest canopy, allowing light penetration which could aid predators in finding active adults, especially ovipositing females. The tendency of birds to seek the safety of trees escaping defoliation could increase the density of predators on larvae feeding on those trees, as well as on ovipositing females.

Air pollution over Pennsylvania is often from industrial areas in the Ohio Valley and Gulf Coast (Brown 1987). Local sources of pollution do not greatly increase the quantity of oxides of sulfur and nitrogen in the sampling area, since the area is not industrial. Despite reports of a two- to three-fold increase in ozone and other oxidants in the Appalachians between 1962 and 1976 (West 1977), air pollution may not be a critical factor in fluctuations in melanic frequencies at this site. Despite high levels of polluted air over Pennsylvania, four of the five species sampled in this report have stable melanic frequencies. The determining factors appear to be localized biological factors, like gypsy moth.

The data here suggest that the widespread aerial spraying for gypsy moth control may be having a catastrophic effect on many species of lepidopterous insects in the eastern United States.

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